GLAZIER (W.C.W.)

TRICHINÆ:

THEIR MICROSCOPY, DEVELOPMENT, DEATH,

AND THE

DIAGNOSIS AND TREATMENT

OF

TRICHINOSIS

BY

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ILLUSTRATED WITH 17 WOOD CUTS.

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NOTE :—As the development, growth and form of the Trichina and Trichina Capsule is the same in animals as in man, no special description of the PORK TRICHINÆ has been thought advisable.

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TRICHINÆ.

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Trichina Spiralis is Professor Owen's name for this nematode, and this is the one now in general use. His description of the male worm, seen figured in Fig. 1, is as follows: "The *male*, in the adult state, is 1.5^{mm} long on an average, and 0.04^{mm} in diameter; it differs from the female (shown in Fig. 2) in form only in the posterior extremity, which offers, in the male, two digital appendages situated laterally, and between which is the cloaca, which is reversed during copulation; the penis is absent, genital tube simple, with a single seminal vesicle in one mass, and a very long vas deferens."

"The *female*, (Fig. 2) is from 3^{mm} to 4^{mm} in length, and 0.06^{mm} in diameter; the vulva is situated near the end of the anterior fifth of the body; the ovary is simple; the ovules, seen through the integuments, have a diameter of 0.02^{mm}; the embryo, hatched in the uterus, is 0.12^{mm} long."

THE DEVELOPMENT OF THE EMBRYO.

On account of the large number of eggs and the length of time during which they are produced, the development of the embryo from the ovule can be easily followed. We can often count from 500 to 600 embryos, and free eggs, in the uterus and ovary at the same time, even for weeks after their production has commenced, and before its termination. I believe, therefore, that one trichina may give birth to a couple of thousand of embryos, at the rate of one to two each hour.

The ovules when detached measure at least 10μ in diameter: the germinal vesicle, about half as much, and the germinal macula about half as much as the germinal vesicle. (See, Fig. 3, *a*, *b*.) After the ovule has increased to double its former size, and becomes somewhat elongated, a few dark molecules may be seen in the vitellus. By this time the ovule has passed into the uterus and becomes fecundated. (See, *c*, Fig. 3). In eggs of larger size are seen two vesicles, often of different sizes, with nuclei, as seen at *d*, *e*, in Fig. 3. *f*, of the same figure, shows segmentation of the nucleus. This process of segmentation is carried on, until about twenty cells have been formed, (see, Fig. 4), when the nuclei are no longer visible, even after the addition of water. (See, *c*, *d*, of Fig. 4.) The ova have now reached a length of 25μ and are somewhat less in diameter. The mass of blastodermic cells now becomes contracted on one side, and presents a pyriform, then a sausage-shaped outline, and by further crooking and coiling it accommodates its increased length to its narrow quarters. (See, *e*, *f*, Fig. 4). On the surface of the worm is now seen a layer of chitine, the interior being formed of uniform cells; its form is plump, and the length scarcely exceeds five times its diameter (see, Fig. 5, *a*.) As the body becomes larger, the organization is perfected by the development of the digestive apparatus.

The future position of the œsophagus is marked by a line of transversly elongated vacuoles. The posterior portion is not yet developed from the blastodermic mass. (See Fig. 5, *b*.) In the further growth and differentiation, the muscular portion of the œsophagus appears, and finally the stomach is separated from the external wall, see, Fig. 6,

a, *b*. The embryos develop and increase in size while in the uterus and vagina. The size of the new-born trichinæ, which have only left their shell a half day or a few hours previously, is from 0.08mm to 0.12mm. The whole development occupies about three days.

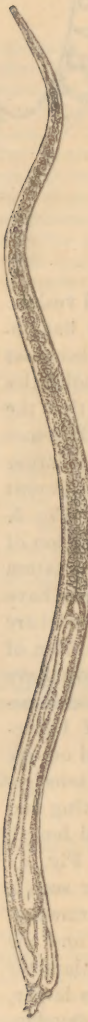

FIG. 1.

Mature male intestinal trichinæ.

The number of embryos that a female may bring forth is variously estimated at from 60 to 2,000. Virchow says that "the pregnant female has one hundred living young in her body, besides numerous eggs, and that she can reproduce young in three or four weeks. Allowing 200 young to every female, of which say 5,000 have been swallowed, which can be easily contained in a small piece of meat, we have then 1,000,000 embryos to commence their migrations." The number 2,000 I believe to be scarcely more than a minimum.

Virchow regards the act of generation as accomplished in a week. Colberg and Pagenstecher in less than that time, since they found them fully ripe on the fifth day in the womb. On the seventh and eight days, according to Leuckart, the expulsion of the larvæ from the mother's womb being well advanced, some embryos have penetrated the muscles in the neighborhood of the adominal cavity. In the intestines the females are found in the mucus, while the embryos are found on the surface of the mucous membrane. Passing through the intestinal wall into the peritoneal cavity, through the medium of the connective tissue, the embryos reach the muscles and destroy the fasciculi. Within the fasciculus they develop in fourteen days to muscle, or larvæ, trichinæ, while the persistent sarcolemma develops, in a few days, into the capsule. In twelve to fifteen days after infection the migration of the young trichinæ, and destruction of the muscle substance is at its height; then comes a remission, through a decrease in the number and

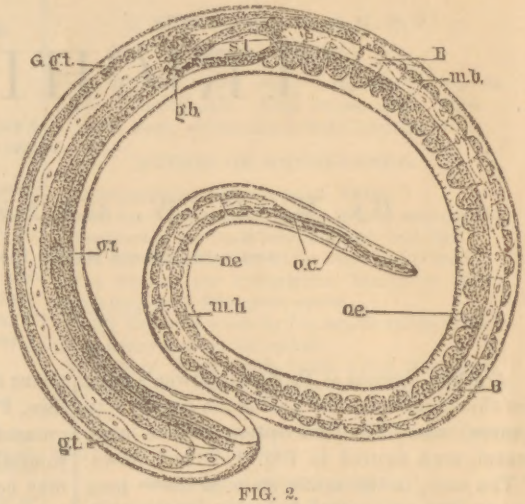

FIG. 2.

Fully developed female muscle-trichina; *o c*, oval cavity; *o e*, œsophagus; *m b*, median band; *s t*, stomach; *g b*, granular body of Farre; *g t*, genital tract.

fruitfulness of the female trichinæ, until their final disappearance, which will be about the fourth or fifth week.

The opinion of Thudicum that it was impossible to account for the rapid dissemination of the embryos throughout the muscular system, except through the medium of the blood-vessels, has not been maintained.

Evidence is lacking to prove that they often, if ever, bore through the walls of the blood-vessels, while they are always found in the earlier periods, in the connective tissue.

Kramer says the trichinæ lay more *between* than within the fasciculi, on the forty-fifth day, and they often do not penetrate the fasciculi until their further progress in the intermuscular tissues is arrested by the insertion of the muscle into a bone or tendon.

On the ground that the blood-current passes directly to the fœtus during gestation, their absence in still-births, caused by trichinosis, has been brought forward to prove their absence from the blood.

I believe that the migration of the trichinæ from the abdominal cavity to the remotest part of the body takes no more than twenty-four hours. Once through the intestinal wall the young animal has nothing in particular to hinder its progress. Its length, as also its

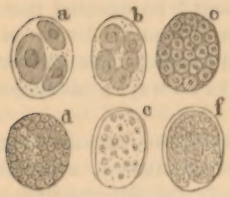

FIG. 3.

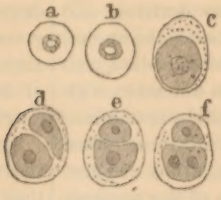

FIG. 4.

FIG. 5.

FIG. 3.—Development of the embryo: *a*, ovum, showing germinal vesicle and macula; *b*, the same increased to double its former size, with no material change in the vitellus; *c*, do. vitellus increased in size, with dark molecules, as it reaches the uterus; *d*, *e*, *f*, segmentation of the vitellus, $\frac{5}{1}\frac{0}{0}$ (Pagenstecher).

FIG. 4.—Development of the embryo. Further segmentation of vitellus; *f*, outline of embryo distinguished $\frac{5}{1}\frac{0}{0}$ (Pagenstecher).

FIG. 5.—Development of the embryo. *a*, the plump embryo, consisting of a layer of chitin filled with cells; *b*, position of œsophagus shown by a faint line of vacuoles $\frac{5}{1}\frac{0}{0}$ (Pagenstecher).

diameter, is so insignificant that it can easily pass without disturbing the connective tissue.

The embryo, first of all, in its course to the muscle must pass through the intestinal wall; though not all will pass through all the layers, a part passing through the mucus membrane and muscular layer, reach the connective tissue of the mesentery, between the two layers of which they continue their way to the vertebral column, and thence to the muscles. I have observed free embryos among the vertebræ, as a rule, in young animals experimented on.

The remaining trichinæ take their way direct to the abdominal cavity, causing an inflammation of the visceral and parietal layers of the peritoneum, which, as the inflammation of the mucus membrane, never fails if the number of trichinæ is sufficiently large.

There is usually in the peritoneal cavity a small amount of dirty exudation, in which are suspended numerous epithelial and fat globules.

These observations not only confirm my assertions in regard to the migration of trichinæ, but still more, they prove that their transit causes a peritoneal irritation.

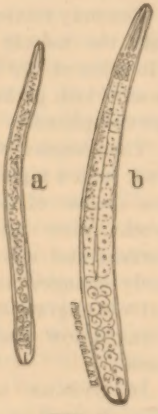

FIG. 6.

Development of the embryo. *a*, trace of outer portion of alimentary canal; *b*, shows chitin tube and brain vesicles $\frac{5}{1}\frac{0}{0}$ (Pagenstecher)

What is not received from the zoologist must be accepted on the authority of the physician, and I consider it settled *that the intestinal trichinæ not only deposit their young in the alimentary canal, but that the latter spread thence through the connective tissue*, although it may happen that single embryos will pass by means of the blood current into the muscles.

The size and appearance of the embryos remain unchanged during migration. The first changes are observed after the worms have reached the fasciculi and taken on a condition of rest.

That it is the fasciculus which is occupied by the parasite cannot be doubted, because the embryos are occasionally seen in fibers, otherwise completely intact, and we are enabled to follow, step by step, the changes which they, with their occupants, undergo, until the latter reach their full development as muscle trichinæ.

The trichina thus enclosed in the sarcolemma destroys the inner parts of the fasciculus, not only in its immediate vicinity, but also as far as the single fiber can be traced, sometimes over 5^{mm} or 6^{mm}.

This destruction consists in a morphological metamorphosis (similar to that found in the so called paren-

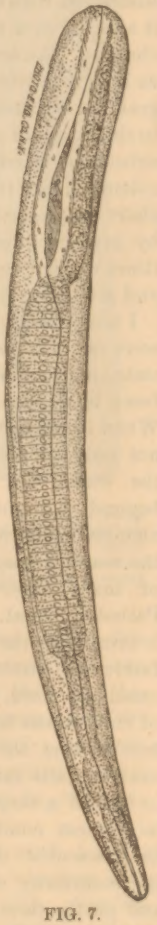

FIG. 7.

Muscle trichina 4mm in length. (Leuckart.)

chymatous myositis); the fibrillar substance degenerates to a fine granular detritus, and all that can then be distinguished is the nuclei, which appear as small, oval bladder-like bodies, 10 μ to 16 μ long, and 4 μ in diameter, with a sharply defined wall, and with a sometimes single and sometimes double solid nucleolus. When two nucleoli are present, they are generally found at the extremities of the nucleus, and the wall will be more or less contracted in the middle. There can be no doubt that this is the beginning of a division into two new nuclei.

This accounts for the fact that the nuclei are always more abundant in the degenerated fasciculi than in the normal.

As the transparency of the fasciculus is interfered with by this change in its substance, it appears as a dark, thread-like stripe. The changed fasciculus loses its contractility, as is shown when the bundle is divided; the granular substance then projects, sometimes to the extent of a millimeter, while the muscle substance is contracted nearly with the sarcolemma, and it is with this projection (Leuchart says later that the projection is caused by pressure) that muscle trichinæ are sometimes carried beyond the limits of the sheath, and are then said to be free.

I have found free trichinæ often, but they were not developed beyond their embryonal state, and they are not found as often as those freed by chance or by the dissecting needle. When it is seen that the fasciculus is changed, not only in the immediate neighborhood of the worm, but for a considerable distance beyond, it might easily be concluded that the change has been produced by the progress of the worm through it, and this is the opinion of many observers. Zenker (Archiv. für Patholog. Anat. Bnd., 18, p. 556) says that it consumes the contractile substance of the fasciculus, but the contents of the alimentary canal are fluid, and probably are the result of endosmosis and are not swallowed; for I believe that the embryo, after reaching the muscle, falls into a condition of rest similar to that of a *chrysalis*, and that in spite of its motionless condition the whole contents of the fasciculus degenerates, partly through the continuity of the contractile substance, and partly through the continuation of the irritation. When the infection is of a high grade, not seldom two or three trichinæ are found in the same fasciculus; sometimes the degree of development is so unequal that the younger must have found its home in an already degenerated bundle. The occurrence of degeneration is, in no way, a hindrance to a new migration.

Simultaneously with the degeneration of the fasciculus there commences a proliferation of small cells in the surrounding connective tissue, which extends over the whole length of the sheath, and in some cases to the neighboring fasciculi.

According to Colberg, the nuclei of the capillary vessels also partake of this change to such an extent that the distribution of the inflammatory products (as also of the blood) is interfered with. The blood-vessels themselves are enlarged and elongated, often taking a "cirsoid" appearance. By many, these changes, at least as far as the contents of the fasciculus are concerned, are supposed to bear a direct relation to the activity of the worm. Zenker, as stated above, thinks that the embryo eats its way through the fasciculus, and that it is possible that the oval corpuscles (muscle nuclei) may be masses of excrement. This is on the supposition that they retain their previous activity. But the same thing occurs here as with the cestoides and other helminths; after reaching their future resting-place they fall into a condition of repose necessary for the growth of the body, and further differentiation of the organs.

The only motion observable, after entrance into the muscle bundle, is an exploratory vibration of the anterior extremity; but this is soon lost, perhaps before the above changes are completed.

Then begins, with the entrance of complete rest, such a rapid growth that the worm, in the course of 12 to 14 days—about three weeks after infection — becomes a fully-formed and matured muscle trichina. The body changes its form. While the embryo, prior to migration, showed a somewhat slender form, it now takes on a more plump appearance.

In trichinæ measuring 0.4^{mm} in length (Fig. 7), such as are usually met in fourteen to sixteen days after infection, the relative thickness is nearly double in the largest part of the body. The anterior third, however, is more slender in proportion to its former state, and diminishes in size to its extremity,

similar to the fully-developed worm. The posterior end also begins to show the abrupt rounding of its future form. Similar changes also occur in the internal organs, which now not only become more distinct than before, but separate into oval tube, cell, body, and stomach, and have a more or less complete distinction in histological character.

The thin chitin tube of the anterior extremity, extending through the cell-body to the stomach, also may be seen, even in worms measuring 0.3^{mm}. The primitive sexual gland is seen in the form of an elongated sac, whose pointed anterior extremity, either extends beyond the stomach, as in females, or in the male, bends abruptly backwards.

The opening into the rectum is first seen in worms of about 0.53^{mm}. The oval tube has a proportionate length, and, near its middle, shows distinctly the first trace of the nervous system, which, in the form of an oval enlargement, is distinguished from the cylindrical mass.

With the more complete differentiation of the internal organs is connected an increase in the size of the whole body. The young worm increases more in length than in breadth and its previous plump form gives place to a more slender appearance; at the same time, the body becomes bent and curved until, after a more considerable increase in size, it finally assumes an irregular spiral position.

In the larger sarcolemma sheaths the coiling commences soonest, when the worm is scarcely 40 μ in length, but is more or less retarded when they are narrower; but it occurs in the narrowest sheaths, even in those whose lumen scarcely exceeds the diameter of the worm. The sheath enlarges around the trichina, and this occurs in the largest sheaths as well as in the narrow ones. It is apparently due to the outward pressure caused by the worm. The spindle shape of the tube is explained by the elasticity of the sarcolemma, which has now lost its delicate appearance. This increase in size stops when the worm comes to maturity, *i.e.*, two, to two and one-half weeks after the worm has reached the muscular tissue. The bright halo surrounding the worm, and, which is now sharply limited by the inclosing muscle, is the optical expression of the enlargement. The contents consist, besides the worm, of the above described granular material, which, even at this period, contains numerous muscle nuclei, which are paler and more transparent than at first.

The enlargements of the sarcolemma show many differences in form and size, sometimes slender and extended, sometimes short and bulging; in one the end abruptly truncated, in others gradually passing into the normal size of the fasciculus. As a rule, the diameter of the sheath is scarcely more than a fourth or a fifth of the length, while the remains of the fasciculus appears as an appendage four times its length (Fig. 8). I have distinguished sexual differences in worms measuring 0.41^{mm} by the form of the genital sac.

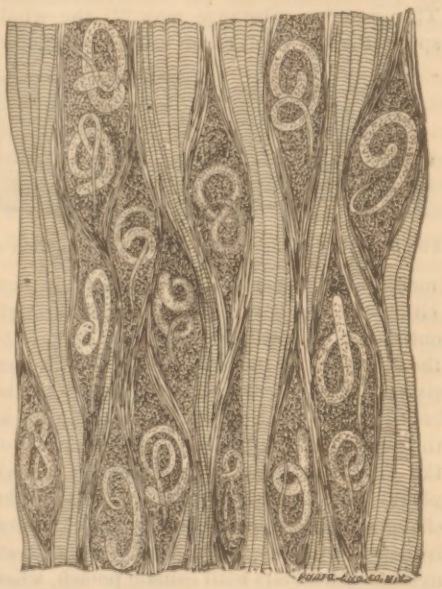

FIG. 8.—After a preparation from a human body dying during the Hedersleben epidemic. Trichinæ probably about seven weeks old, completely developed, but without a trace of a capsule; spindle-shaped enlargements of sarcolemma were present (Leuckart).

The migration of the trichinæ during this time has not for one moment ceased, and they may be seen in all stages from those just arrived in the tissues to those measuring 0.7^{mm} in length and completely coiled. In these cases the slender end is more closely coiled than the posterior, which lies in the periphery of the coil.

In the rabbit, after the sixth week, I have found no living trichinæ in the intestine, and only a few in the fourth and fifth. Fiedler gives 34 days and Pagenstecher 56 days as the

last appearance of trichinæ in the intestine. I have found them in the hog in the twelfth week. In the Hedersleben epidemic intestinal trichinæ were found in the seventeenth week.

In the fifth week, or as late as the sixth, after infection the trichina lies in the above-mentioned tubular sheath, which, on account of the presence of the parasite, has become spindle-shaped, and has a double contour. Besides the parasite, the contents consist of a granular mass, with the oval muscle nuclei. Sometimes the enlargement is long and slender, gradually lessening to the original size of the fasciculi, or it may be short and thick. The granular substance may fill the whole space (Fig. 9), or in other cases the enlargement, with a well-defined constriction near either end, has only scattered masses throughout the tube. I believe this constriction to be the first trace of the capsule, and that it consists of a deposit of a clear substance in the inside of the sheath in the form of a ring at the capsule (Fig. 10), and the later capsule of the muscle trichina is produced by a peripheral consolidation of the contents of the changed sarcolemma sheath. This opinion is further strengthened by isolation and treatment of older cysts with caustic potash, when a line of the same substance (chitin?) can be traced from one pole around the periphery of the sheath to the other.

FIG. 9.—Spindle-shaped tube before encapsulation commences (Leuckart).

After seventeen weeks the trichinæ lie in a clear space, 0.4 to 0.5^{mm} long, inclosed at the extremities and having a clearly defined outline. The tubular portion of the sheath disappears, and in its place is seen only a line of connective tissue, rich in granules, abutting against the end of the connective tissue inclosure. But without a knowledge of the previous condition nothing abnormal would be suspected. The capsule, by proper and careful treatment with alkalies or acetic acid, could be turned out of its sheath. These capsules are still thin, and sometimes of so little firmness that they may be bursted with slight pressure. Their walls consist of a clear, structureless, stratified membrane, with numerous molecular granules similar to, but in less number than, those found among the nuclei in the contained space. The proportion of the length to the thickness is, as a rule, 4: 3, although there are shorter capsules of a more bulging form, and they may even be spherical. Their length is about 0.4^{mm}.

Davaine, quoting Bristow and Rainey, says that the cyst is simple and the product of secretion of the worm. The walls are distinctly laminated, but the lamination is not sufficiently uniform to warrant the assertion that there are two walls. Generally the layers are partly separated, and the spaces are filled with granular matter.

The lamination is more distinct at the extremities, where the wall is thickest and more condensed, especially in the citron shaped cysts, whose tap-like, projecting ends are completely solidified, so that the contained space has a simple oval form. The contained worm (three months after infection) is completely grown, but the granular body of Farre cannot as yet be seen.

The surrounding sarcolemma still retains its former appearance, and is about 1 μ thick over the lateral walls of the cyst, but projects beyond the ends, sometimes in a lengthened

FIG. 10.—First trace of capsule.

FIG. 11.—Encapsulated trichina showing sarcolemma sheath and cell proliferation (Leuckart).

tip (Fig. 11), or may be more open, and shorter. The latter is the most usual form. The ends appear as if cut off, but in many cases they can be traced for some distance as delicate, pale tubes, apparently the remains of the original appendages. As a rule these can be followed only a short distance from the capsule. Sometimes they are very irregularly serpentine or coiled.

After fifteen weeks the side walls of the capsule have a thickness of about 26μ. The inner surface of the capsule presents, in many cases, the appearance as if lined with pavement epithelium, occasioned by the presence of numerous muscle nuclei which are closely pressed against the wall, some of which also seem to be inclosed in its substance.

After injection, the connective tissue envelope shows a rich net-work of capillary blood-vessels (Fig. 12) described by Luschka, and which, according to Colberg's investigation, proceeds from the small proliferative cell seen in the commencement of the new formative connective tissue, etc. Each pole has an independent vascular system with afferent and efferent vessels, which connect with the muscle capillaries.

CALCIFICATION OF THE CAPSULE.

Fürstenberg saw the beginning of calcification in a rabbit eighteen months after feeding. Pagenstecher gives eighty days for the first appearance of calcareous concretions in the rabbit, and although it has been denied by Haubner that calcification occurred in the hog, he, Pagenstecher, saw traces after one hundred days. The first case in which trichinæ were observed in the hog (Prof. Leidy) contained calcified capsules. Dr. Müller (Virch. Arch., 1866, p. 253) found degenerated capsules in the hog. Delpech reports, on the authority of Dr. P. Niemeyer, the occurrence of calcified trichinæ capsules in the muscles of a hog confiscated in Neustadt in Madgeburg. Leuckart saw traces of calcification in a hog five months after infection. Friedrich saw capsules with commencing calcifications on the one hundred and first day. Warfwinge saw signs of calcification after six weeks, and E. Wagner (Arch. der Heilkunde ii, 1864), in two cases, after twenty-three and twenty-six days respectively, claims to have seen trichinæ encapsulated and partly calcified. Gerlach (Die Trichinen, Hanover, 1873, p. 4) saw trichinæ capsules thirteen and a half years old in different degrees of calcification; some were completely opaque, some partly transparent, and others having the deposit only at the poles, and says that it is an error to pretend that calcification occurs before the eighteenth month. Damman (Deutsch. Zeitschrift, Bd. 3, 1876, p. 92) found capsules uncalcified eleven and one-fourth years after feeding.

The process of calcification, according to Leuckart, is as follows:

There is seen, beginning at either pole of the capsule, a more or less flask-shaped or spread out accumulation of minute calcareous granules, which may remain isolated for some time, or soon become a homogeneous mass, having the form of a disk and lying between the layers of the capsular wall. Sometimes, this process takes place at one pole only. In all cases its margin is well developed, and from its different refracting power, is readily distinguished from the surrounding mass. In a hog killed six and a half months after feeding (with trichinosed meat), I saw capsules in which there was not a trace of calcification; others were found as above, but, in the greater number, there was an irregular concretion which sometimes, with the adjoining uncalcified layer of the capsule wall, projected like a hump (buckelformig) into the cavity. These occurred mostly in the citron

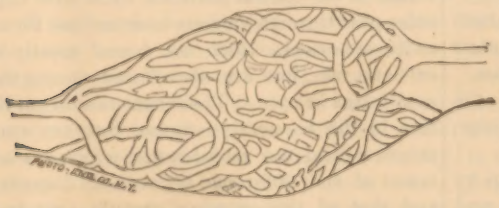

FIG. 12.—Network of capillary blood-vessels surrounding sarcolemma sheath (Pagenstecher).

shaped capsules, but in those more nearly globular, the disks were more the shape of a watch glass. I found the first trace of fat globules in this case. I cannot tell when the process is completed, but probably after fifteen or sixteen months more. In hogs, this process commences after six months in most cases. Fiedler says the seventh and eighth, and Pagenstecher the eighteenth month. Nevertheless, there is great variety and irregularity, perhaps due to idiosyncracies. Sometimes capsules will be found without a trace of calcification in bodies, when the rest are completely calcified. The process does not stop with the calcification of the original capsule; the latter becomes thicker at the expense of its contents, and after a long time the worm itself may be changed.

Gerlach says:

"The stage of capsule formation begins in the third and ends in the eighteenth month after feeding on trichinosed meat. At first, after the capsule is completed, there occurs a shrinking which lasts two months, the capsule becoming somewhat thicker and rounder, after which it remains unchanged for four or five months. In about six months, sometimes sooner, groups of fat globules are seen in the vicinity of the poles; after twelve to fifteen months, the fat globules appear in the capsular walls. * * * The stage of calcification, beginning in the eighteenth month, in some capsules appears quite distinct in the second year. In the early months of the third year, a few capsules are nearly opaque, and can be seen by the naked eye as small bright points about the size of a pin's head in the surrounding muscle."

RECAPITULALATION OF THE DEVELOPMENT OF TRICHINÆ.

Tenth day.—Completely developed intestinal trichinæ and a few embryos migrating towards the muscles.

Twentieth day.—Muscle trichinæ about one-half their usual size; some embryos, none capable of development to muscle trichinæ.

Fourth week.—Oldest and most of the trichinæ fully developed; traces of capsules; high grade of myositis.

Sixth week.—Sheaths begin to close up by condensation of nuclei against the wall, and from thence they project towards the middle, forming an arch at the end; some trichinæ in open sheaths as in fourth week.

Second month.—Capsules fully formed; same as in sixth week.

Third month.—All the capsules are fully formed; inflammatory process is ended; surrounding muscle regains its normal appearance; finely granular substance at the poles.

Ninth month.—The capsules become shorter and nearer round; greater or less number of fat globules are found particularly at the ends of the capsules, but they are absent in some cases.

One to one and a half years.—Fat globules in the capsules and outside, especially at the poles; traces of calcification.

After one and one-half years commencing, and after two years, distinct calcification, but not in capsules.

The worms may be found free in the muscular tissue in recent cases, but as a rule they are encapsulated. In old cases the capsules may be seen with the naked eye as small white dots in the red of the surrounding muscle. This appearance is due to the deposit of particles of lime salts, which by the addition of a weak solution of HCl., are dissolved when the bodies lose their opacity. Previous to calcification the capsules cannot be seen by the unaided eye. Under the microscope with a power of 10 to 12 diameters these points appear as oval or spheroidal cysts, inclosing a small round worm, coiled spirally, whose outlines are more or less distinct according to the degree of calcification (Fig. 8).

The capsules found in human muscles are oval, as a rule, with the long axis lying in the direction of the fasciculi (Fig. 13); the poles are usually more or less drawn out to a pointed top, which sometimes gradually enlarges in the centre to inclose the cyst, and at others butts against the body of the capsule so that the whole takes the form of a citron. By reduction of the pointed extremities, and an increase in the central portions, these oval capsules pass through various intermediate forms to the spherical, which are found mostly in cats and rats, but are also found among the oval forms in man. These capsules do not lie free in the connective tissue, but are contained within the sarcolemma, which on account of the difference between its diameter and that of the growing capsule exercises more or less pressure on the latter, causing

Fig. 18.—Cyst magnified 300 diameters, commencing deposit of fat cells at the extremities of the cyst (Kœstner).

more or less deviation from the spherical form, as this pressure is exercised to a greater or less degree.

The size of the capsules varies even more than their form. With a diameter of 0.2^{mm} to 0.4^{mm} there will be a difference in length from 0.3^{mm} to 0.8^{mm}. The normal average may be taken at about 0.4^{mm} for length, and 0.26^{mm} for breadth. The difference in form relates more to the external outline than the cavity, which in almost all cases has a simple, more or less, shortened oval form, which gradually decreases in size through thickening of the walls, which latter may reach a thickness of 28 μ.

When, as sometimes occurs, the capsule contains more than one worm—two (Bowditch), three (Farre), and even four and five worms have been observed in the same cyst—it is more or less elongated, according to the number of the contained trichinæ, while the diameter seldom shows any increase. As a rule they lie behind each other, with more or less space intervening.

Under higher powers the wall of the capsule has the appearance of a delicate diagonal fibrillation. It is, however, doubtful whether this appearance is due to the presence of real fibres or to the peculiar grouping of the molecular granules which are distributed through the otherwise perfectly clear and homogeneous basis substance. More distinct, however, is the stratification of the wall, which is seen more particularly in the solid extremities, but can be easily recognized where the wall is of a moderate thickness.

The capsule containing trichinæ bears no similiarity to the connective tissue envelopes of the cysticercus and other peripheral helminths. On the contrary, it is so similar to a chitinous membrane that we cannot avoid the conclusion that it is a product of secretion of the enclosed worm, and corresponds with the capsules of certain other helminths, particularly the Tetrarhynchice and Trematodes. This view is also supported by its reaction with caustic alkalies, and also that it is changed but little by an increase of temperature.

The lime salts deposited, after a time, produce a granular condition of the walls; but these lime granules should not be confounded with the molecular granules above mentioned, as they are larger and disappear with effervescence on the addition of the stronger acids. They are found most plentiful in the extremities and in the outer layers, and in more complete calcification the whole wall is thoroughly impregnated, when it may lose its transparency; yet the outlines of the inclosed worm can generally be made out and the true nature of the body be easily determined.

The calcification is not uniform in any case, and, as may be seen by experiment, some capsules will be thoroughly impregnated, while others show scarcely a trace of deposit. This will be the better understood when we remark that the capsule has an independent vascular system developed from the interfascicular capillaries. This network has no special relation with the capsule proper—which is independent of the surrounding connective tissue—but spreads over the envelope of sarcolemma, as first observed by Farre. Sometimes this external envelope is very much increased in thickness, so that the diameter of the cyst is increased by one-half. At the poles of the capsules when the muscle fasciculi are separated to receive them will be seen numerous fat

globules. At the same time the vessels will be seen spreading over the surface of the capsule in the form of a network, which has its greatest development in the equatorial zone. Generally only one vessel is seen at each pole, an afferent and an efferent, corresponding in size to the muscle capillaries, so that they may be considered as artery and vein. When more than one is found their combined caliber rarely exceeds that of a muscle capillary.

The cavity of the cyst contains besides the worm a finely granular, tolerably clear fluid, with numerous ellipsoidal bodies 10μ to 15μ in in length and 5μ to 8μ in diameter, which through the clearness of their outline and the existence of a distinct body, sometimes double, of a cellular appearance, and by its resistance to acetic acid, may be recognized as a nucleus. They are probably the nuclei of the disintegrated muscular fibers. This fluid, on the addition of alcohol or glycerine, coagulates to a jelly-like mass, in which we are sometimes so fortunate, after careful section, as to have a complete impression of the inclosed worm.

In capsules taken from fresh, warm muscle, there will be more or less motion of the anterior extremity of the worm, and it may even change the position of its whole body. In other cases the worm will be seen in coils of four or five turns, and motion will be observed, perhaps, only after moistening with warm water or solutions of caustic potash. This condition of rest is that most usually seen and generally depicted by observers.

The inclosed worm is 0.8^{mm} to 1.0^{mm} in length. The anterior half is more slender than the posterior (which measures 33μ), and gradually decreases in size to the head, which can readily be distinguished at first sight from the posterior rounded extremity. At either end will be seen a small opening continuous with a delicate tube of chitin, which extends through the whole length of the body. The general external and internal organization resembles the early forms of the trichocephalus, excepting that the latter is extended, while the trachina is more or less coiled up, and retains this position even when freed from its capsule, which is most readily accomplished by scraping and chopping the trichinous meat and washing out the worms. The position of the intestine leaves no doubt that the concave side of the curved animal is the back, which, as has already been remarked by Bristowe and Rainey, is always in the same direction as is the case with the full-grown male trichocephalus.

The cuticula covering the body is thin (1μ), transparent, and excepting its delicate annulated appearance, is of a perfectly homogeneous nature. The presence of the rings is easily overlooked, excepting where they are increased in depth by the contraction of the concave back of the worm. Internally the wrinkled cuticula is covered by a layer of tolerably clear substance, which in its deeper portions shows a distinct longitudinal striation, and incloses numerous bodies (nuclei?). I am not prepared to state whether this is muscle or not.

The viscera fill the cavity of the body [abdominal cavity] so completely that their external surfaces are in contact with the inner surface of its wall; only at the extremities is there any space left, which, besides a few masses of cells lying against the wall, contains a clear, highly refractive liquid, which may be correctly considered the analogue of the nutritious fluid of other nematodes. In many cases, also, a thin layer of this fluid may be seen under the lateral walls of the body.

The intestines and organs of generation hang free in the cavity of the body, being attached only at their extremities.

The most striking and peculiar part of the intestinal canal is the œsophagus (See Fig. 14), which extends through more than half the length of the body, and except the posterior third, which incloses the stomach and genital tube, leaves free only a small portion of the anterior extremity. The oval cavity from which this cellular body proceeds, appears as a clear cylinder of small diameter, which sometimes is straight and at others more or less crooked from contractions of the part which contains it, and fills up the space otherwise filled with the nutritious fluid. Within this cylinder is contained a double contoured narrow tube of chitin, which connects the almost punctiform mouth with the œsophageal tube; the latter, commencing at the anterior extremity of the cellular body and instead of a muscular coating, passes beside it through its whole length.

The muscular nature of the oval cavity is very indistinct, the wall appears clear, and, except the posterior part, which shows signs of radiating lines, is completely homogeneous.

Near its middle this elongated cavity is surrounded by a clear annular body, containing distinct cells, which are connected with the wall. There can be no doubt that this is the nervous centre of the trichinæ, as Pagenstecher traced some nerve filaments which passed thence backwards and forwards on the wall.

The peritoneal covering of the first portion of the intestinal tube extends over the œsophagus and cell body in the form of a thin sheath, and on account of the swelling of the individual cells has an irregular, knotty apparance. Farre considered the œsophagus of the trichinæ as analogous to the colon.

The contents of the cells are distinctly granular, sometimes clear and at other times darker, not only in different individuals, but in different cells in the same individual, showing a probability that they are subject to frequent and rapid changes in connection with the conjectured absorption of nutritious substances, which are easily seen on account of the thinness of the œsophageal tube.

The posterior portion of the body is filled as completely by the stomach and genital organs as is the anterior part by the œsophagus, without, as might be expected, any considerable increase in the diameter. The stomach (Fig. 14) presents a flask-like enlargement at its anterior extremity, which is of nearly the same diameter as the œsophagus, and presents a large cavity, while that of the latter appears as a capillary tube.

Covering this structure is a structureless *tunica propria*, a direct continuation of the peritoneal sheath of the œsophageal apparatus, within which is seen a moderately thick, sharply-outlined layer, containing a greater or less number of yellowish, shining, fat globules, which appear in some localities, especially in the fundus of the stomach, as a layer of flattened cells, as has been observed by Luschka.

The posterior extremity of the intestine, although differing a little externally from the stomach, is histologically a very different structure. It has, like the oval cavity (Mundrohr), an external thick muscle-like wall, and is lined by a narrow tube of chitin which is continuous through the arms with the external cuticula. It forms the rectum of the trichina.

The genital organs, which usually in the larval stage of nematodes are only primitive, have in the trichina an unusual development (Fig. 15). They consist principally of a gland in the form of a broad sac in the convex ventral side, which extends through the whole posterior part of the body and crosses the intestine to the opposite concave side of the body. Although thicker than the intestine and of a different appearance, it has hardly been seen by former observers, except Luschka, and even he gave a very imperfect description of it, because he overlooked the fact that this sac ended anteriorly in a thread-like extension which represents the later developed excretory apparatus, and that through the peculiarity of its appearance the sexes might be distinguished. Yet they are very similar in the male and female. In both it consists of a cylinder of delicate membrane 25μ in diameter, filled with pale nucleated cells 3μ

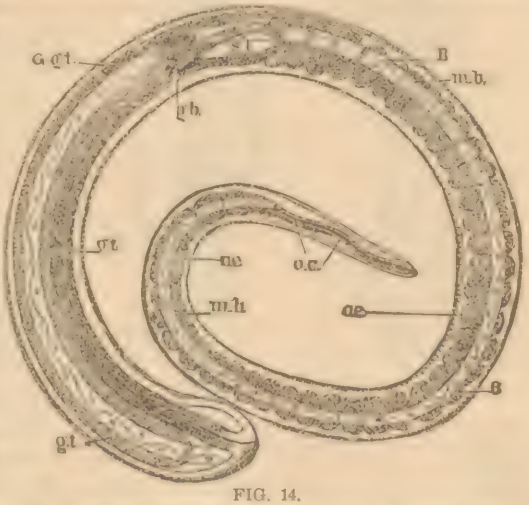

FIG. 14.

Fully developed female muscle-trichina; *o c*, oval cavity; *o e*, œsophagus; *m b*, median band; *s t*, stomach; *g b*, granular body of Farre; *g t*, genital tract.

in diameter and ends in a blind sac or pouch at the beginning of the rectum, lying free in the abdominal cavity. The anterior portion, which reaches to the fundus of the stomach, becomes narrower, and in the older muscle trichinæ, with calcified capsules contains a considerable number of sharply contoured corpuscles of irregular form and strongly refractive, which was observed by Farre and thought by him to be the ovary. The true nature of this structure is unknown. Even its chemical constitution has not been discovered, and it is uncertain whether it is an excretion or whether it is a result of a fatty metamorphosis of the cellular contents of the genital glands. Only so much is certain that they have no connection with the future growth of the sexual organs nor with the development of the ova, and are not reached by the larvæ.

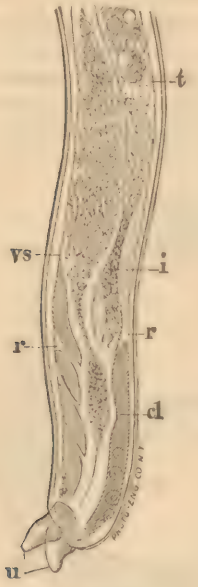

Fig. 15.—Posterior extremity of young male intestinal trichina, $\frac{320}{1}$: *u*, hooks, *cl*, cloaca; *r r* retractores cloacæ, *vs*, vesicula seminalis; *t*, extremity of the testicle; *i*, intestine (Pagenstecher).

Fig. 16—The testicle, *t*; vas deferens, *vd*; cloaca, *cl*, with its retractors, *r r*; intestine *i*.

The excretory apparatus proceeding from the anterior extremity of the genital glands appears in the female muscle trichina (Fig. 14) as a direct prolongation of the genital sheath, while in the male (Fig. 1), at a short distance from the granular body of Farre, it turns sharply on itself and is connected with the anterior part of the rectum. This duct in the female not only has another direction, but passes between the cell body and the ventral wall to the anterior part of the body. Its anterior extremity cannot be seen even with a microscope, and I think it is not yet in connection with the abdominal wall. The histological character of this body is not as yet well defined either in the male or female. It consists of a fine row of cells which only in the vicinity of the genital glands shows the traces of a lumen, but otherwise appears as a solid structure.

In the male, where the vas deferens, a short distance in front of the anus, empties into the rectum, which latter acts as a cloaca, is developed a network of fine fibres between the muscular layer and the intestine, in which a few distinct bands are seen (Fig. 15), whose functions seems to be the withdrawal of the projected cloaca after copulation—the *musculi retractores cloacæ*. Anterior there is no connection between the intestine and the outer wall.

At the vagina the external walls are continuous with those of the sexual organs, and naturally the most external layer—the chitin layer—is continued as a lining of the digestive tract and sexual organs.

The body is more or less curved in one direction, and taking the female genital opening as a guide for the ventral surface the curve is always towards the back side, and it is in accordance with this that the terminal hooks of the male are found on the opposite side, and curving towards the convex and consequently ventral side. The anus is therefore terminal, although in the female on its dorsal side there is a small but distinct prominence. This is the rudimentary tail usually found in the nematodes. As a rule the posterior portion of the male is straighter or is curved in an opposite direction from that of the middle portion; especially is this the case during the period of sexual activity. It is then more firm, and displays a motion similar to that of the anterior.

The internal sexual organs of the male are completely formed during his larval life in the muscle, so that in the intestine it is only necessary that their contents become mature and the hook developed in order that he may

be ready for procreation. In the larval female these organs are only partially formed until it reaches the intestines, and thus different stages of completeness will be found among the intestinal trichinæ.

The male organs (Fig. 16) consist of a single testicle, the base of which lies a short distance from the posterior extremity of the worm. It is long, cylindrical, somewhat widened at the base, and becomes narrower as it passes forward, and near the anterior portion of the stomach turns on itself, becomes still narrower, and passes backwards. In a full-grown male the testicle is 0.575^{mm} in length, while its average diameter is 35μ, but reaches 0.375^{mm} in some places, while in the vicinity of the vas deferens it is only 20μ. This gland in its whole length is lined and filled with small, strongly refracting seminal vesicles, which, as mother cells, contain a brood of spermatic cell elements with nuclei. The testicle merges into a vas deferens, which, in places, particularly before it empties into the intestine or cloaca, expands, and near its extremity forms the vesicula seminalis, and is filled with spermatic elements, which latter have not, as far as observed, been known to undergo any change of form. The vas deferens, exclusive of vesicula seminalis, is 0.3^{mm} long, and when not distended is 12.5μ to 15μ in diameter, and when empty appears clear and lined with cells. Three fourths of its length is occupied by the seminal vesicle, which, partly full and partly empty, with a constriction at its middle, reaches a diameter of 50μ.

When the vas deferens is seen thus enlarged but empty, and the hooks extended and spread out, it may be concluded that the semen has been ejected. The great tenacity with which the male adheres to his place in the intestine, and the vivacity with which the female, already containing spermatic elements, views the approach of the male, shows that coition takes place repeatedly.

The complete act of copulation I have never observed. I nevertheless have several times found masses of males and females entwined together, slipping over and encircling each other and performing a variety of motions. At the same time the posterior extremity of the male is stiffened and rhythmically projected and withdrawn, while his anterior extremity and the whole body of the female are very active, often coiling completely and uncoiling. The actions of the male while approaching the female consist in gliding the hind part of his body over the body of the female in a longitudinal direction, and embracing the latter with the terminal hooks, and when loosened, the cloaca is sometimes seen to project in the form of a minute bell or bladder, with seminal elements adhering.

The female organs of generation consist of a single ovary, which is formed during its larval existence; a uterus, which develops from its anterior extremity; a vagina, which is developed immediately backwards from the vulva, which already exists on the external surface. By a constriction between the ovary and uterus they are more perfectly separated than are the testicle and vas deferens, but the uterus merges gradually into the vagina. After complete development the uterus may be considered as a direct widening of the vagina. The whole series of organs lie in a nearly direct line.

The ovary, in form and position, bears a great similarity to the testicle, but reaches further to the rear—nearly to the rounded extremity of the body—but not so far forward, a large portion of the uterus lying behind the commencement of the stomach.

The ovules—as Clann has correctly observed—are not produced exclusively in the vicinity of the fundus of the ovary, but are formed at one side of its walls in its whole length, where they first appear closely pressed together in a narrow band, which on account of the fine molecules scattered among the cells has a darker appearance than the rest of the ovary, and near by are seen the more mature and detached ovules, so that the largest are found on the opposite side of the ovary and towards its anterior extremity. Thus the oviduct is a part of the same organ. The ovules are roundish and contain a germinal vesicle with a very large nucleus surrounded by a clear vitellus and a very thin limiting membrane. Between the ovules, seminal elements are sometimes seen in the lower part of the ovary. The cylindrical uterus is separated from the ovary by a constriction, so that the narrowed exit is somewhat bent, and its entrance into the uterus is overhung by the blind extremity of the latter. It is in this

Fig. 17.—Portion of a female muscle trichina in which Farre's body, *f*, is formed, and in which the 7 collosal cells which form the primitive trace of the uterus are seen; *l*, longitudinal band, $\frac{300}{1}$ (Pagenstecher).

part of the uterus that the sperm is principally found after copulation, so that the ovules passing from the ovary must pass through it and be subjected to its fructifying influence. There occurs thus in the uterus a further growth and development of the cells, and it is filled with ova in various stages of development, which, as they approach the beginning of the vagina, are freed from their envelope and appear as bent or curved embryos.

A little in front of the posterior extremity of the œsophagus, where the uterus becomes narrower, they commence to straighten out and lie parallel to its long axis. Further on the narrowing becomes such that beyond in the vagina they lie singly behind each other and are born one at a time. During and after delivery the border of the sexual opening protrudes beyond the surface of the body forming a conical projection. The posterior lip is more fully developed than the anterior. The whole of the sexual tract is lined with small nucleated cells, which are somewhat elongated in the vagina and lie in the direction of its axis, but become somewhat indistinct at its extremity, so that at the vulva, which is only large enough for the passage of a single worm, no further structure can be seen.

The position of the vulva also changes in accordance with the size and degree of development of the worm. In trichinæ of 1.2^{mm} to 1.4^{mm} in length, in which as a rule the vulval opening is completed—although exceptionally some may have become pregnant when only 0.9^{mm} in length—its distance from the anterior extremity is between 0.175^{mm} and 0.3^{mm}; in diameter it was 0.35^{mm}, though these figures may vary considerably.

The first appearance and growth of the vulva and lower part of the vagina can be clearly observed in young nematodes. At the place where the vulva is to appear there is seen an elongated mass of small cells, which is directed backwards (Fig. 17), but as yet no opening is seen. The uterus is now projected forward by the accumulating mass of ovules from the ovary. The separation of the uterus from the ovary is distinctly formed before the vulva is opened—about the time the worm coils up previous to encapsulation—but is not yet completed in some old muscle trichinæ. At this time there lies beside the stomach in the axis of the prolongation of the ovary, and separated from the latter by the constriction and Farre's granular body, a small single row of about six or seven corpuscles, with distinct nuclei, which I have considered young ovules (Fig. 17), becoming more plainly visible after the worm has remained a short time in the intestine. At this time, before the two parts are joined, detached eggs of an oblong form may be seen. In forty-eight hours this phase of development is completed, and copulation may take place, followed by the birth of the young brood in five days. Many authors are of the opinion that there are many more females than males found in the intestines. This is true to a limited extent, although in our investigations the females, which are larger, and, on account of the contained brood, much darker and more readily seen, yet in the earlier periods I have found more males than females, for the former are not so easily evacuated with the diarrhœal discharges as the heavier females. In one case I found ten males to one female, but in others I have found many more females. I believe that in the beginning the sexes are very nearly equal, but that the males, whose functions are sooner completed, disappear earlier, and in later periods their number is more diminished than that of the females.

PATHOLOGICAL ANATOMY OF TRICHINOSIS.

In the first four weeks the microscopic appearance of the body is not at all characteristic, although the most prominent symptoms of the disease are in progress at this time. Besides the subjective symptoms, pain, feeling of tension, dyspnœa, etc., two objective symptoms are especially prominent. The peculiar position on the back, with the angular contractions of the elbows and shoulder and

light flexion of the hand, the complete extension of the thigh and leg, and the elasticity of the muscles, which continues after death.

The anatomical changes in the alimentary canal compared with the severe symptoms—vomiting, the severe and obstinate diarrhœa, which as often alternates with as obstinate constipation—are very insignificant. In the first four weeks there is only the appearance of a more or less fresh catarrh, pale grayish cloudiness of the mucous membrane, roundness and slight swelling here and there of the solitary follicles, small areas of hyperæmia or hæmorrhagic spots. The lymphatics, perhaps, partake of the same general condition. The mesenteric glands are constantly swollen and infiltrated at first with a soft gelatinous substance, which in the later weeks is hard, grayish white or yellowish gray, as in ilio-typhus, returning in very late stages nearly to their former shape, yet somewhat enlarged, flattened, hard, and of a grayish white or pale gray color. These enlargements can be considered at first as a consequence of the severe enteric metamorphoses or as a consequence of the presence of the migrating trichinæ if, as Virchow believes, trichinæ occur in them, which, however, is denied by Cohnheim.

Stomach.—Kratz (p. 75, *op. cit.*) "found one case with ulceration of the stomach, but doubts its casual connection with the ingestion of trichinæ, and quotes a similar case in Quedlinburg." Ebstein (*Wien. Med. Presse*, 13, 14) in one case "found numerous round ulcers in the stomach and duodenum." Klob (*Wien. Med. Woch.*, No. 11) reports one case in Brünn where "peritonitis followed the rupture of a duodenal ulcer." Cohnheim found three cases of ulceration of the stomach, and Wolff (*l. c.*) found them "in a man previously sound who, during an attack of trichinosis, died of hæmatemesis, but there was an old ulcer in which the eroded artery, from which the blood came, was found." Wyss found ulcers in the stomach of a cat. "Thus, ulcers of the stomach and intestine are not uncommon, and may lead to a fatal result" (Meissner, *l. c.*). In a case reported by Dr. Gilpin, "the stomach and intestines were empty, and showed evidences of prolonged congestion."

Liver.—Of the above cases mentioned by Kratz, a fatty condition of the liver was found in nearly every one; and in only two cases observed by him were there any symptoms referable to that organ during life. Two cases by Maddren (*l. c.*) the liver was fatty. Hun (*l. c.*) found the liver clay-colored and very much enlarged. Boehler (quoted by Kesleuch, p. 35) mentions one case of fatty liver in which death occurred after nine weeks. Dr. Gilpin, Milford, Ind. (*American Practitioner*, September, 1879), in one case there was only a slight congestion of the left lobe of the liver.

Spleen.—In Dr. Gilpin's case the spleen was swollen, darker and firmer than normal. Warfwinge (*l. c.*) found the spleen enlarged. Hun found it normal. Cohnheim, according to Renz (p. 39, *op. cit.*), found fatty metamorphoses of the spleen in one case. In one case (see Aitken, *op. cit.*, p. 160) trichinæ were found alive in the spleen. Maddren (*Kings County, New York, Med. Soc. Rep.*, 1879, p. 181) in one of two fatal cases the spleen was slightly enlarged; in the other it was normal, which is the condition in most cases reported.

Kidneys.—In Dr. Gilpin's case the left kidney was congested, with small calculus in its pelvis. In two cases by Maddren (*l. c.*) there was congestion, and a small cicatricial nodule was found in one. Warfwinge (*l. c.*) found parenchymatous nephritis in one case; Cohnheim, fatty degeneration, one case. (See also Renz, p. 39). Otto (*Memorabilien*, No. 10) found considerable reddening of the pyramids and a purulent effusion in the pelvis. Other cases were normal.

Bladder.—Generally, if not always, normal.

Peritoneum.—Mostly normal or slight reddening, "with (in animals) a dirty effusion containing embryos, pus and fat globules." (Leuckart.)

Respiratory Tract.—"The muscles of the larynx are notoriously infiltrated with trichinæ. In the fourth week there is not seldom a profuse bronchial catarrh, and a further inflammatory process in the parenchyma of the lung and pleuræ, which may cause death. Cohnheim (*l. c.*) found in most of his post-mortems a reddening of the bronchial mucous membrane; the latter was also covered with a tough, glutinous slime, and there was hypostatic congestion and splenization of the lung, and in seven cases there was real infiltration." Meissner (*l. c.*). In fourteen cases examined in Hedersleben (Meissner, *op. cit.*, 138, p. 95), the pathological condition of the

lung was due to hypostasis, while thrombosis and embolism, which Rupprecht says is the cause of trichinous pneumonia, did not occur. Of seven cases examined by Rupprecht fatal pneumonia existed in six, of which the left lung was affected alone in five cases, and a double pneumonia existed in one. The autopsy showed circumscribed conical infarctions in the affected lung, with the apex towards the root of the lung and the base towards the pleural surface. The branches of the pulmonary artery ending in two infarctions were filled with embolic clots riding on the septum between the two branches at the bifurcation.

SYMPTOMS.

I have followed Renz in the symptomatology of the disease, but have introduced points from Leuckart, Kratz, Scoutetten, Kestner and others, which, as a rule, are placed in brackets, with initials of author's name.

From a few hours to a few days after the ingestion of the trichinous flesh the patient is seized with symptoms of indigestion; complains of nausea, cardialgia, belching, diminished appetite; the tongue is coated; there is fœtid breath, vomiting, or eructations; a feeling of general weakness, and prostration and utter exhaustion [or they complain of feeling so tired, Kratz, Rupprecht, Maddren, Sutton]; there are flashes of heat, rigors [perhaps a chill—Kratz], fullness of the frontal region [or headache—L.], vertigo, lancinating and flying pains in a few groups of muscles, particularly in nape of the neck and flexors of the extremities. After two or more days there appears a choleraic or diarrhœic discharge from the bowels. The vomited matter is first slimy, then bilious. The stools, at first brownish and streaked, take on the clay-like character of many typhus stools. Severe neuralgic pain is almost always present in the abdomen, and pain is felt in the arms and legs, and sometimes in the intestines.

In the severest cases the patient may suddenly die at this stage of the disease with all the appearance of cholera, or from extreme exhaustion. Those who do not vomit now and then become by degrees excessively debilitated. As the stools become less copious and less frequent they still retain their clay-like appearance. The pain in the abdomen becomes somewhat duller. Thus pass the first eight days of the disease. The diarrhœa may pass off soon and give place to an obstinate constipation, or may continue in the second stage of Rupprecht—*stadium digressionis*.

The most important and constant symptoms of the second stage are œdema (which, according to Kratz, commenced oftenest on the tenth day) and profuse perspiration. The skin is covered with sweat, which is acid, persistent, abundant, and often of a nauseating odor (K., p. 64). This stage (Renz) is ushered in usually on the seventh or eighth day with œdematous swelling of the eye-lids, which often spreads to the neighboring parts, and sometimes is associated with a light form of conjunctival catarrh; occasionally the pupils are dilated and photophobia is present. The power of accommodation is diminished and the eyes may be fixed (Kittel, *l. c.*), indicating the presence of trichinæ in the orbital muscles. Pain in the orbital muscles, often occurring in the fifth or sixth week, especially in the morning, is present in all the severe cases, and subscleral ecchymoses sometimes appear. The œdema of the eyelids does not last long and in some cases is very light so that it may not be noticed—or it may be entirely absent—and sometimes it disappears to reappear after four or six weeks. It reaches its maximum of intensity in persons of lymphatic temperament and in thin skinned persons, as in women and children, and is not dangerous unless it invades the larynx or meninges, which is most liable to occur in fat persons (K.). The fever suddenly increases, and may reach 104° Fah., with the pulse at 80 to 120 per minute or more, but is occasionally very light or even absent—(Jackson); an unquenchable thrist and an overwhelming sense of heat torments the patient; the tongue is furred, yellowish white, or covered with a black, sooty, clammy coating, soon losing all epithelium, becomes of a uniform dark brownish red; it is smooth and covered with papillæ or blisters—the latter manifestly not due to direct migration of trichinæ while eating the infected meat, as is held by Rupprecht (Meissner, *op. cit.*, No. 122, p. 222; No. 138, p. 93) — and suddenly — generally in the night—there occurs extreme dyspnœa, often lasting for several hours and sometimes recurring daily for weeks (sometimes the diaphragm sinks down and remains in a state of tetanic rigidity). The brain, for the most part, is undisturbed; or coma, due to dis-

turbed respiration, may occur after attacks of dyspnœa. There is a total indifference to surroundings, but a great fear of death. Insomnia is present in adults, but does not often occur in children, who are more apt to be soporose. Colic and mesenteric neuralgia come on with migration of trichinæ in the second week. There is hyperæsthesia of the skin; more rarely there is formication in the height of the disease, with tumefaction and œdema of the lower limbs, and, in one case, in the fifth or sixth week there was complete anæsthesia, lasting one day; singultus was present once, through complication in the cerebellum" (Meissner, *op. cit.*, 130, p. 94). Pleurodynia is sometimes present and delirium is occasionally permanent. (Sc., p. 67; also Kratz.) Hearing is frequently impaired (Meissner, *l. c.*). If the patient previously has not been too much debilitated or exhausted by the disease he may pass through this ordeal, but many succumb in a short time. Then the muscles of the neck, loins and limbs, particularly the flexors, show more or less stiffness and increasing tenderness, which latter is constantly found, on pressure, in the epigastrium. Œdema, commencing in the roots of the limbs, proceeds towards the digital extremities. Motion is extremely painful; the elbows are bent and the knees drawn up. (The contraction of the flexors, constant in the onset of the disease, is sometimes accompanied, in advanced stages, with a tetanic rigidity of the neck, back and loins, and often by lockjaw. Kratz.) The patient finds ease only by lying flat on his back. (Children usually lie on the side with knees drawn up, the elbows fixed, and are plunged into a profound sleep. Rupprecht, Kratz.) Extension of the ever-progressing myositis is indicated now by the trismus, stiffness of the tongue, difficulty of swallowing, hoarseness, the asthmatic cough, and arrested stools. Severe sweating occurs, sometimes followed by miliary eruption. (Ischuria of a low grade often occurs—Meissner, *l.c.*) As a rule there is an extraordinary decrease in diuresis. Rupprecht found no albumen, but Maddren found it in one case, and it has been found in others. Jessnitzer found involuntary diuresis five times; Kratz only once; then in the coma preceding death. (Jessnitzer gives cases of pustular eruption and herpes, petechiæ ecthyma, and furnculi, often seen after the subsidence of sweating.)

As a rule the disease will now turn (except in individual cases) towards a favorable termination and be completed in a few weeks. But in the severest cases, which frequently progress to a fatal termination, the pulse increases to 120–130 or more, per minute, and is small and weak; the fever takes an adynamic character and the patient becomes apathetic. Trismus, when it exists, is augmented; the tongue, though more movable, is dry and trembling; respiration becomes more labored, and the patient lies flat on his back. In short, all the appearances of a fatal case of typhus fever are presented. In cases which progress towards recovery, there is a decrease of fever in the fifth week and the pulse sinks to 90 or less, the appetite improves (*becomes ravenous*, L. Kratz), the perspiration becomes less copious and the urine increases in quantity, sometimes suddenly, and the œdema rapidly disappears, and the only remaining symptoms are slight pains in a few muscles, emaciation, weariness and lassitude.

A large number of the cases reaching the seventh week progress regularly to convalescence; a few somewhat lighter or partly abortive cases are entirely recovered, and show only in their complete emaciation the appearance of having passed through a severe sickness. Very many of these attacked later are still confined to their beds with weak compressible pulse (96 to 132), little or no appetite, and troublesome thirst; the muscles of mastication are more or less swollen and rigid, and the still dry tongue can only with difficulty be projected. In some cases deglutition is difficult, the voice is still weak, suppressed, or hoarse; sometimes there is œdema of the skin of the thorax; pressure leaves no marks, or only those quickly effaced, and sometimes is extremely painful. The respiration is mostly superficial, short, and accelerated. The intercostal spaces do not recede on inspiration, and the thorax moves as a whole, as in unilateral pleuritic effusion, when motion of the intercostal muscles is interfered with by the pressure of the liquid; yet a really pleuritic effusion is never found in trichinosis; the peritoneal cavity shows signs of a greater or less degree of ascites; the urine is scanty and high colored; the bowels remain unopened on account of weakness of the abdominal muscles, and some patients cannot raise themselves un-

der any circumstances, and when helped complain of pains in the back and loins, and show a tendency to double up. The lower extremities are greatly swollen, one often more than the other, half bent, or, if extended, then abducted; the skin readily yields to pressure, to a greater extent in most cases as the foot is approached; such pressure generally produces considerable pain. The legs often present the appearance of *phlegmasia alba dolens*. The arms are swollen more seldom than the legs, the swelling oftener confined to one side, and the forearms are generally half flexed; the flexion can be completed without disturbing the patient, but the slightest attempt at extension produces severe pain. The skin frequently changes in temperature and is often very moist from perspiration. In most cases the patients were very much relieved after sweating commenced. Then once or twice daily there occurs a most frightful paroxysm of depression, which, after intolerable heat and agony of suffocation, ends in a refreshing diaphoresis.

DIFFERENTIAL DIAGNOSIS.

Influenza—Would not be apt to be accompanied by severe stomach or intestinal symptoms. The cough in this disease is severe, and sputa, profuse and yellow, most troublesome at night, and accompanied with a severe headache. The inflammation generally commences in the ocular and nasal mucous membranes and extends downwards, and when lung symptoms occur they are marked by well defined physical signs (which is not the case in trichinosis) "and it may terminate in diarrhœa, while trichinosis is more apt to commence with diarrhœa, or vomiting, or both."

Rheumatism.—The parts affected by acute rheumatism are for the most part the joints and such textures as are composed of white fibrous tissue, "while the latter affects the bodies of the muscles (the pain when it appears, is diffused, as a rule—Kratz), and pain, on passive motion, is due to motion of the inflamed muscles on each other. The sub-facial œdema will not be present in rheumatism, while the joints will be hot, red and swollen. Pain is not usual in præcordium, and when present in rheumatism other signs of cardiac inflammation will appear. Rheumatism will not occur as an epidemic."

Gout—Does not often attack any joint but the first one of the great toe, in other words, it is rare for the first attack instead of being a *podagra* to be a *chiragra*, *gonagra* or *omagra* (Niemeyer). The previous history of a case would have a strong influence on the diagnosis, yet a previous history of gout should not necessarily preclude the possibility or even probability of trichinosis, as high livers are apt to lunch often, and raw or underdone ham is frequently used in public places for lunches. In trichinosis the pain commences centrally and presses towards the extremities.

Sudor Anglicus, or sweating disease (Niemeyer) with which the epidemic at Wegeleben (and probably in other places) was confounded, has many symptoms in common with trichinosis. This disease is limited to certain parts of Europe, and rarely, if ever, occurs in isolated cases. When its presence may be suspected, a thorough examination of food and a close study of the history of the case would lead to a correct diagnosis; but the existence of the premonitory symptoms, with those conditions of the muscles and skin most characteristic of trichinosis, would be the most reliable guide, as an epidemic of any magnitude would hardly occur without some of these symptoms being present.

Cholera.—The similarity of trichinosis to cholera was so great in the Hedersleben epidemic that it led to a false diagnosis in many cases, and cholera morbus, which generally shows its effects in the night, might easily be mistaken for the former disease. In all such attacks it would be well to give due consideration to a possibility of trichinosis, with especial inquiry regarding the ingesta of the previous day. A possibility of cholera invasion would be increased by its previous occurrence in other, especially neighboring localities. The pain on pressure occurs in cases where there is no diarrhœa or vomiting. The peculiar stitching pains and feeling of tension in trichinosis develop later. The remission of pain and tension in cases of cholera, after perspiration occurs and absence of pain in epigastrium, would then settle the question.

Typhus Fever.—This disease differs materially from trichinosis, besides the most apparent symptom of the former, is the rash, which appears from the third to the fifth, or as late as the seventh day. (But the rash is absent in 25 per cent. of cases below 15 years, 14 per cent. from 18 to 22 years. In cases above 25 years

it is always present—Aitken). In the cough of typhus the sputa is of tough mucus, occasionally mixed with blood (Niemeyer), while that of trichinosis will be negative, as it is due to irritation of the larynx. The temperature in typhus is high during the first week, whereas in trichinosis it is not much elevated until after the first week. In typhus the spleen early shows signs of enlargement, but there are only two or three cases of such an enlargement in trichinosis; but in the latter the liver may exceptionally be very much enlarged. Œdema, muscular tension and contraction is absent in typhus, while in trichinosis the arms are generally flexed. "In typhus the arms lie beside the body helpless."

The only important symptom of typhoid fever said to be absent in this disease (trichinosis) is enlargement of the spleen, and it is very probable that some of the so-called epidemics of typhoid fever in former days were caused by the propagation of trichinæ in the human body. But the epistaxis, the pain and gurgling on pressure in the right iliac region, the rose-colored eruption of typhoid fever, cannot exist in trichinous diseases, while the irritation of the stomach and bowels, with œdema of the face and severe muscular pain, especially on motion, with breathlessness, increasing to dyspnœa or almost asphyxia, ought to render the parasitic disease easy of diagnosis from enteric fever (Aitken).

PROGNOSIS.

The mortality in different epidemics of trichinosis is widely different, and depends on the degree of infection and severity of the disease, but children suffer less than adults.

Of 67 children under 14 years attacked in Hedersleben one died—1.5 per cent.; of 100 women 17 died, 17 per cent.; of 170 men 83 died, 48.8 per cent., or nearly 30 per cent. of all cases. In Plauen in 1862 the mortality was 6 per cent.; in Calbe, 20 per cent.; in Burg, 22 per cent. In Hedersleben the mortality was very irregular in the different periods. Two died during the first week, a few in the second. The mortality increased towards the third week, and three-fourths of the deaths occurred during the fourth, fifth and sixth weeks, after which the death rate decreased and none died after the tenth week. Of 8 fatal cases in Plauen 1 died on the fourth, eighth, fourteenth and forty-second day, and 4 on the twenty-first day. In Hettstadt the greatest mortality occurred in the fourth and fifth weeks, *i. e.*, during the time that myositis was most severe. A few died earlier, some later, the last through marasmus, in consequence of a purulent breaking up of atelectatic nuclei or from follicular disease of the intestines, or from muscular atrophy. The more extensive an endemic, the more intense will be the disease. The earlier the disease supervenes on the infection and the more complete and severe the symptoms are developed—swelling and tension of the muscles, formication, prone position, stiffness of the body, trismus, dysphagia, severe diarrhœa, temperature 106° F., pulse over 120, respiration over 32, dyspnœa, embolism of the lung—the more unfavorable the prognosis.

Schenck, of Halle, divides the symptoms into three sets for prognosis. "1st. Where there was severe diarrhœa after one or two days, lasting several weeks, the prognosis is most favorable. 2d. Where there was a slight diarrhœa after six or eight days, with sudden cessation, the patient most frequently dies. 3d. The lightest cases are those in which the symptoms appeared after two or three weeks. According to Meissner, these observations were not confirmed in the Hedersleben epidemic, for severe stomach symptoms appeared early in some cases, later in others, and in another set not at all, without influencing the prognosis." One of the last category was, in Hedersleben, very severe. Death occurs most frequently in the fourth or sixth week after infection. Implication of the muscles of respiration is the most frequent cause of death, but it seldom reaches a fatal condition before the fourth week, or comes on later than the fifth. In the gravest cases typhoid symptoms set in during the fourth week. In some cases in Hedersleben, as in Hettstadt, there would occur an entire remission of symptoms, which might be followed by a sudden significant exacerbation, speedily ending in death. Sometimes death follows from gastro-enteritis before any signs of peritonitis or migrating trichinæ were observed.

TREATMENT.

The therapeutics of trichinosis deserve no great praise. Means by which the muscle or intestinal trichinæ can be destroyed have not, after the most careful search, been found.

Calomel has been prescribed to evacuate the intestines by way of the rectum. I would recommend a one-half per cent. solution of chloride of sodium, at 98° Fahr., or a blood-warm solution of salicylic acid.

Pagenstecher says: "In the first period give calomel and jalap p. āā 1.0 to 1.5 grams, and later, oleaginous emulsions and sulphur made into pills with glycerrhiza radix."

Virchow says: "As a rule, when there is a probability of infection, powerful evacuants, with or without previous anthelmintics, are indicated."

Rupprecht recommends calomel, "not only because of unirritating qualities, but also on account of its parasiticidal qualities as demonstrated in its effect on the anchylostomum duodenale in Africa. Other anthelmintics are of little use. Castor oil is less energetic than calomel as a cathartic. One of the best informed practitioners of our province has expressed the opinion that in case he was called to treat trichinosis he would commence with inunctions of mercurial ointment and keep them up every hour until salivation was produced. But the trichinæ, when brought into contact with particles of mercury, do not seem to be affected. The weakening influence of severe salivation, with the accompanying fever, is greatly to be feared in some cases, and in light ones would not be necessary."

Kratz says: "Rupprecht warmly recommends scruple doses of calomel, and, as long as we have no real anthelmintic against trichinæ, I look upon it as a very useful remedy on account of its beneficial action on the mucous membrane of the alimentary canal. I have occasionally combined it with santonine. I have, however, seen salivation follow after the use of one scruple of calomel; certainly a very unfortunate complication in such a disease. The anthelmintic effect of calomel is, to say the least, very doubtful."

Infusion of quassia, so destructive to ascarides, might on trial be found to destroy the trichinæ in the intestine. The solid extract would be the best form, administered in pills and perhaps combined with sulphur.

Drs. Ritter and Von Brenner used ℞ Cupri acet., ʒi; aquæ cinnimoni, mucil. gum arabic, āā ʒ i; aquæ font., ʒ vj, in teaspoonful doses, and found it very useful in connection with salt-water baths.

Dr. Dirke found the hydrarg. cum creta recommended by Traube to have the best effect as an anthelmintic and antiphlogistic in the cases treated in the charity hospitals.

Rhode found morphia and ergotine useful antipyretics, but according to Levy ergotine has not been sufficiently tested to warrant an opinion. The use of salicylic acid seemed to make the patient restless.

Friedrich used picro-nitrate of potash with good results, while Fielder found the picro-nitrate of potash and soda entirely useless.

Veh. says: "Iron was useless against the œdema of the lower extremities, but digitalis and increased diaphoresis by means of hot bottles did good service, as did also cold sea-baths. Warm baths did little good.

Kramer found that warm baths decreased the pain.

Mosler concludes that the lack of any symptoms of trichinosis during life or of intestinal trichinæ after death in a steer fed by him was due to the use of benzine, as a calf that had been fed by Leuckart with trichinous meat died of *enteritis trichinosa*. Ad. v. Dirke found benzine (Mosler), picro-nitrate of soda (Friedrich), oil of turpentine (Behrens), ext. felix mas. æth. (Küchenmeister) of little use.

Flogel used turpentine. Owing to its known irritating effect on the stomach and kidneys gives it in small doses, often repeated, rubs it on the swollen parts, and administers it by inhalation. He treated successfully filaria in the eye of a horse with turpentine.

"Benzine was administered by Kratz to the extent of one fluid dram daily with no other effect than that fewer trichinæ were found after death in the intestines than after the use of opium." (Because it did not have the same constipating effect?) Meissner recommends thalium or lithium carbonate with sulphur præcipitatum.

Behrens (*l. c.*) suggests the salts of lime to favor calcification. In cases where patients drop off suddenly while apparently feeling well as, in Maddren or Bergen's cases, artificial respiration should be resorted to. The effects of amyl-nitrite and electricity should be tried.

There were several cases in Hettstadt in males who drank notable quantities of brandy and escaped infection, while their families, partaking of the same meat, became seriously ill. Another man who drank two bottles of red wine experienced no inconvenience after eating trichinosed meat. Alcohol, according to Rupprecht, kills trichinæ in a few hours.

In conclusion it may be said that there are no medical preventives, *i. e.*, medicines which protect against trichinosis when trichinosed meat has been eaten. It may be that in a great many cases such or such a remedy might apparently have prevented the development of the disease, or rendered it insignificant. In such cases the meat has contained but few trichinæ, or the subject has a strong constitution. If there is a substance which will kill the parasite in the stomach or intestines it has not been found yet. If such an agent can be found, of which there can be no doubt, it certainly will not be an ordinary remedy, as wine or brandy, spices, etc., but a true medical substance. Such a remedy can never be used as a prophylactic.